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GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE SOUTH HALF OF THE CAÑADA GOBERNADORA QUADRANGLE, ORANGE COUNTY, CALIFORNIA

1974

CALIFORNIA DIVISION OF MINES AND GEOLOGY

PREPARED IN COOPERATION WITH THE
COUNTY OF ORANGE DEPARTMENT OF BUILDING AND SAFETY,
ROAD DEPARTMENT AND THE ORANGE COUNTY FLOOD CONTROL DISTRICT.

SPECIAL REPORT 111

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Special Report 111

GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE SOUTH HALF OF THE CAÑADA GOBERNADORA QUADRANGLE, ORANGE COUNTY, CALIFORNIA

This report is based upon work completed in 1970.

by

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1974

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CONTENTS

Page

SUMMARY AND RECOMMENDATIONS-------------------- 1

1. Slope stability-------------------------- 1
2. Seismicity------------------------------ 1
3. Expansive earth materials---------------- 1
4. Loss of mineral resources---------------- 1

INTRODUCTION---------------------------------- 2

GEOLOGIC SETTING AND STRUCTURE---------------- 2

SEISMICITY AND ACTIVE FAULTING---------------- 4

SLOPE STABILITY SUMMARY----------------------- 5

MINERAL RESOURCE POTENTIAL-------------------- 8

APPENDIX - DESCRIPTIONS OF GEOLOGIC UNITS------ 10

SURFICIAL UNITS---------------------------- 10

BEDROCK UNITS------------------------------ 16

SELECTED REFERENCES--------------------------- 27

LIST OF ILLUSTRATIONS

		Page
Figure 1	Regional seismicity, Cañada Gobernadora Quadrangle	4a
Figure 2	Historic Earthquakes Potentially Damaging to Structures in the Cañada Gobernadora Quadrangle	5a
Plate 1	Geology of the South Half Cañada Gobernadora Quadrangle (Geologic map and cross sections)	In pocket

SUMMARY AND RECOMMENDATIONS

The critical engineering and environmental geologic problems of the south half of the Cañada Gobernadora quadrangle are summarized below in the approximate order of their overall importance.

1. Slope stability is the most significant geologic problem in the area. Areas lying in and marginal to the Cristianitos fault zone contain extensive landslides. The reasons for this are varied and complex. Sites for engineering works in these areas should receive detailed investigation and the application of extensive remedial-preventative measures. In the eastern parts of the area that are underlain by Trabuco and Williams Formations, hazardous rapid-forming mud-debris flows have been prevalent during periods of intense rainfall. These flows are formed near the heads of steep reentrant canyons and flow at great speeds down narrow drainage courses for as much as several hundred yards. Other hazardous rapidly developed failures occurring within the area are rock-falls and stream bluff-failures. (See Slope Stability Summary.)

2. Seismicity and active faulting are hazards prevalent throughout California. The closest faults likely to produce earthquake damage to structures in this area are the San Andreas, San Jacinto, Elsinore-Whittier, and Newport-Inglewood fault zones. The recency of activity of the Cristianitos fault remains questionable at this time, and should be investigated in more detail. Development of this area is taking place at a rapid rate. The most severe ground response can be expected to be on Quaternary alluvium, especially where the ground water level is within thirty feet of the surface. Ground water levels should be determined as part of geotechnical investigations preceding development on Quaternary alluvium. (See Seismicity and Active Faulting.)

3. Expansive earth materials are common in the area. Areas most affected by expansive materials are underlain by the Monterey and Capistrano Formations, the upper beds of the Santiago Formation, and river terrace deposits. The determination of expansivity and the selection of appropriate remedial measures should be required preceding construction in these areas. (See Appendix, Description of geologic units.)

4. Loss of mineral resources due to incompatible developments in this area should be avoided by appropriate planning and zoning. Mineral resources within the study area judged to be of commercial value are sand and gravel in San Juan Creek and lower Bell Canyon, specialty sands in the lower beds of the Santiago Formation, and petroleum from subsurface strata of the Schulz Ranch Member of the Williams Formation.(See Mineral Resource Potential.)

INTRODUCTION

This study was undertaken between 1965 and 1970 through a continuing cooperative agreement between the County of Orange (Department of Building and Safety, Road Department, and the Orange County Flood Control District) and the State of California, Division of Mines and Geology.

The southwest quarter of the quadrangle was released as open-file map number 68-5 in 1968. This has been revised and is included here as a part of the south half. The north half of the quadrangle was published as Preliminary Report 10, in 1970. Other previous mapping in the area includes a number of Masters theses noted under Selected References below. Partial coverage is to be found in Blanc and Cleveland (1968) and Woodford (1925). Reports concerning contiguous areas to the northwest, west and southwest are in various stages of completion by the California Division of Mines and Geology at this writing. (See Fife, Edgington.)

Cooperation of the following parties is gratefully acknowledged the preparation of this report: Atlantic-Richfield Company; California Department of Water Resources; Humble Oil Company; F. Beach Leighton and Associates, Inc.; O'Neill Ranch; Tsvi Meidav, University of California at Riverside; County of Orange, Surveyor's Office; Department of Building and Safety, Road Department; Orange County Flood Control District; Shell Oil Company; Southern California Edison Company; Takeo Suzuki, University of California at Los Angeles; The Texas Company; Toups Engineering; U.S. Forest Service; R.F. Yerkes and J.G. Vedder, U.S. Geological Survey; U.S. Soil Conservation Service; all property owners.

Field mapping was done directly on the U.S. Geological Survey topographic base enlarged to 1 inch equals 1000 feet. This mapping was augmented by interpretation of aerial photos produced in 1939, 1946, and 1970 by Fairchild Aerial Surveys, U.S. Department of Agriculture, and E.L. Pearson and Associates, Inc., respectively.

GEOLOGIC SETTING AND STRUCTURE

The south half of the Cañada Gobernadora quadrangle lies near the southeastern tip of Orange County on the southwestern flank of the Santa Ana Mountains in the Peninsular Ranges of southern California.

The stratigraphic units within the quadrangle are transitional between the units of the Los Angeles basin on the northwest and those of coastal belt of San Diego County on the southeast. All of the formations mapped are identified with units of the Los Angeles basin. Many of the units including the Ladd, Silverado, Sespe, and Vaqueros Formations wedge out completely, or nearly so, toward the southern part of the mapped area. The rock units found within and in areas adjacent to the south half of the Cañada Gobernadora quadrangle range in age from Jurassic to Holocene and can be grouped into two major subdivisions, the subjacent rocks and the superjacent rocks, separated by an unconformity.

The subjacent rocks include complexly deformed and slightly metamorphosed Bedford Canyon Formation and Santiago Peak Volcanics, and granitoid igneous rocks which intrude those units. They were labeled the "eastern bedrock complex" of the Santa Ana Mountains by Woodford (1925, p. 170). They underlie all of the superjacent series of units at depths ranging from eight to ten thousand feet along the western edge (Yerkes, et al, 1965, fig. 2) and crop out along the eastern edge of the quadrangle.

The superjacent series consists of an essentially homoclinal sequence of marine and nonmarine sedimentary formations that lie with angular unconformity on the subjacent rocks. Generally, the strata strike north to northwest and dip gently to moderately westward. Gentle warps are evident locally, whereas steep dips are common near the larger fault zones.

The homoclinal sequence is interrupted by the north-trending Mission Viejo fault that bisects the area and that extends several miles north and south of the mapped area. The Mission Viejo fault is a vertical or steeply-dipping normal fault along which Upper Cretaceous strata on the east apparently have been raised against Paleocene and Eocene units on the west. Vertical separation appears to be on the order of 700 feet south of San Juan Canyon to more than 1000 feet between Bell and San Juan Canyons. Within the quadrangle, no units younger than Eocene appear to be cut by this fault.

The dominant structural feature within the area is the Cristianitos fault zone. This regional northwest-trending feature extends from offshore near San Onofre, 14 miles south of the area, across the west margin, and northward to the vicinity of Santiago Creek, a total distance of more than 30 miles. The fault zone along much of its course consists of sub-parallel anastomosing shears or branch faults. The largest of these has been given a separate name, the Forster fault. The Forster fault branches from the main branch of the Cristianitos fault zone just south of the quadrangle and is believed to join a west branch of the zone just north of San Juan Creek. In turn, that west branch joins the main branch near Plano Trabuco three miles farther north. At their point of farthest surface departure, the horizontal distance between the Forster fault and main branch of the Cristianitos zone is on the order of 5500 feet. The main branch of the Cristianitos fault zone is essentially a high angle normal fault that dips steeply westward and demonstrates a vertical separation of as much as 2500 feet south of San Juan Creek. Juxtaposition of sharply contrasting rock types and numerous landslides along its course give rise to sharp topographic expression. In this area the Santiago Formation of Eocene age on the east side of the main branch is faulted against San Onofre Breccia and Topanga Formation on the west. These in turn are faulted against the Monterey Formation on the west side of the Forster branch of the zone. Nothing was noted to reveal whether any lateral displacement has occurred along the Cristianitos fault zone. Pleistocene river terrace deposits of San Juan Creek do not appear to be affected by the fault zone; however exposures showing detailed relationships along the west branch of the zone were not found.

SEISMICITY AND ACTIVE FAULTING

The Cañada Gobernadora quadrangle, as all of the State of California, lies within a seismically active belt that rings the Pacific Ocean. Any discussion of seismicity must consider its regional aspects inasmuch as large magnitude earthquakes affect areas many times the size of this quadrangle.

Large earthquakes of magnitudes of 7.0 and greater can be expected to occur along at least one of the great earthquake producing faults in the southern California region within a period equivalent to that of the historic record. The historic record, though fragmentary, began in 1769. The most likely earthquake generating faults in the region, together with their closest proximity to the mapped area are the San Andreas (42 miles), San Jacinto (30 miles), Elsinore-Whittier (8 miles), and the Newport-Inglewood (8 miles). A less significant fault suggested to be active within the range of influence is the Norwalk fault, which lies about 16 miles to the north (See Fig. 1) (Richter, 1958). The seismic hazard of the Cristianitos fault zone is open to question at this time .(See below.)

Large shocks originating within a fifty-mile radius could cause high intensity response within the area. How intense this might become is not possible to predict at this time, but ground response would be greatest in the mostly unconsolidated Quaternary-aged deposits, especially where ground water levels are within thirty feet of the surface (Meidav, 1966.) Next most vulnerable would be the Tertiary and Cretaceous sedimentary rocks that are steeply dipping, followed by flatter-lying strata, and lastly, by Santiago Peak Volcanics. Interfaces between rocks of contrasting induration are more susceptible to adverse response than homogeneous materials; therefore construction of critical structures (i.e., hospitals, schools, dams, etc.) astride contact zones between grossly different rock types should be avoided where possible. If such sites cannot be avoided the planned structures should be designed to survive the effect of differing ground response in the foundation materials.

Some degree of differential settlement can be expected in slopewash and older and younger alluvium due to severe shaking. Shaking may also trigger rock-fall in cliff-forming materials, and bedrock landslides in rock units which are most susceptible to such failures .(See Slope Stability Summary.)

No instrumentally recorded epicenters lie within the mapped area. Epicenters of magnitude 5.5 and 4.5 with numerous aftershocks have been recorded in an area centered about eight miles to the north in upper Trabuco Canyon in May, June, and July of 1938.

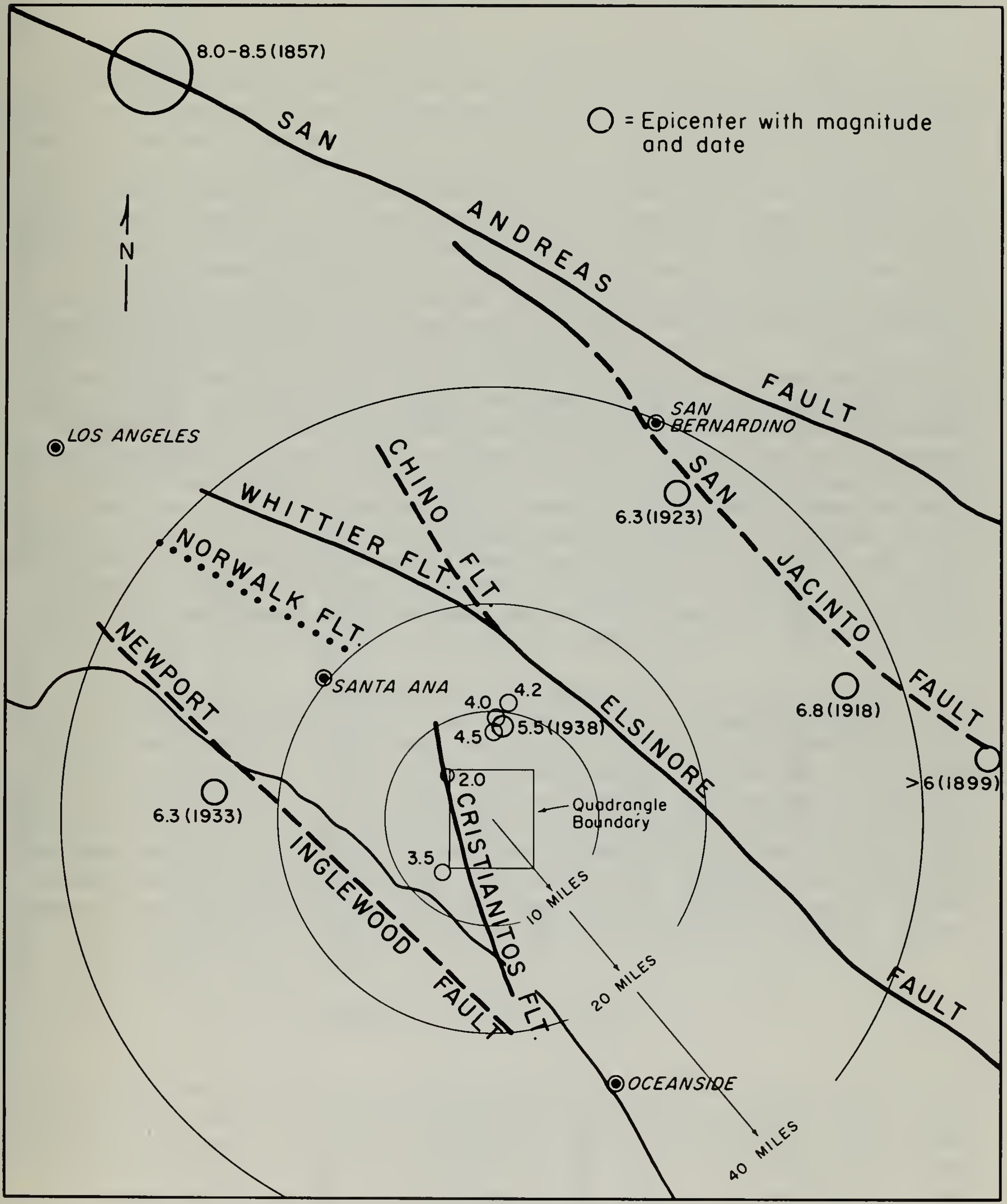

Figure 1. REGIONAL SEISMICITY, CAÑADA GOBERNADORA QUADRANGLE

A summary of historic earthquakes that may have caused structural damage in the area is given in the table below. (Figure 2.)

Only one of the faults mapped in the area was found to have any evidence suggesting displacement of Quaternary age. The Cristianitos fault zone, which traverses the western edge of the quadrangle, was examined closely during this study in order to evaluate recency of movement. No definitive evidence, however, was found within the quadrangle to establish movement since deposition of Pleistocene river terrace deposits of the Trabuco Canyon drainage. A bulldozer trench in Tijera's Creek along the main or eastern trace of the fault zone was excavated by the Southern California Edison Company in 1969. This excavation demonstrated no disruption of the terrace materials by the main branch of the fault zone. Attempts to expose other traces of the zone at that time were unsuccessful. However, a back-hoe trench placed in 1971 by the Division of Mines and Geology about two miles farther to the south in the San Juan Capistrano quadrangle did expose a western branch of the fault. This trench showed apparent displacement of a two-foot thick soil cover along two shears a few feet apart. Maximum dislocation of the soil-bedrock interface was approximately two feet. As this evidence suggested possible late Holocene movement, additional trenching was placed in the same area by the Southern California Edison Company in June, 1972 in order to check this possibility. The additional trenches were observed by representatives of the U.S. Geological Survey, the Southern California Edison Company, the California Division of Mines and Geology, the Orange County Road Department, and the Orange County Building and Safety Department.

These excavations suggested that the apparent disruption of the soil cover may have been due to a combination of (a) animal borings and (b) differential erosion of the bedrock surface with subsequent soil deposition. However, Holocene movement has not been ruled out. To satisfactorily resolve the problem the author believes that additional trenches exposing the base of Holocene alluvium are necessary. Three epicenters that plot on the San Juan Capistrano quadrangle to the west can reasonably be attributed to the Cristianitos fault zone, though this is not necessarily true. These data are presented here merely as additional evidence to be considered in evaluation of the activity of the fault.

SLOPE STABILITY SUMMARY

Slope stability varies greatly from one area to another in the south half of the Cañada Gobernadora quadrangle because of differing geologic conditions. An extensive area of landsliding occurs adjacent to and along the Cristianitos fault zone which transects the western quarter of the map. Landslides cover more than one-third of this area, and composite slides as great as 630 acres are present. By contrast, less than one percent of the remaining area to the east is covered by landslides.

Fig. 2 HISTORIC EARTHQUAKES POTENTIALLY DAMAGING TO STRUCTURES IN THE CAÑADA GOBERNADORA QUADRANGLE.

Date	Approximate area of origin	Modified Mercalli Intensity Near Origin	Magnitude
1769, July 28	Not known but noted by Portola expedition near mouth of Santa Ana Canyon	?	?
1812, December 8	Not known but severely damaged Missions San Juan Capistrano and Santa Ynez	IX-X	>7*
1857, January 9	Fort Tejon region	X-XI	>8.0*
1892, February	Baja, California	?	7.0*
1893, April 4	Newhall	VIII-IX	?
1899, December 25	San Jacinto-Hemet	IX	7.0*
1918, April 21	San Jacinto-Hemet	IX	7.0*
1923	San Bernardino	?	6.0*
1933, March 10	Long Beach (offshore)	IX	6.3
1938, May 31	Santa Ana Mtns (Upper Trabuco Canyon)	VI	5.5
1956, January 3	Glen Ivy (Riverside Co.)	VI	4.7

*estimated magnitude

Factors which contribute to landsliding along the Cristianitos fault zone are varied and complex. They include (1) zones of structural weakness due to deformation along the fault (2) contrasting cohesive strength between juxtaposed units (3) over-steepening due to active erosional processes (4) earthquake shaking (5) complex bedding configuration (6) meteoric water influx due to the presence of sheared zones and (7) inherent weakness of the Monterey and Capistrano Formations.

The main branch of the Cristianitos fault zone is as much as 30 to 50 feet wide and consists of fine gouge, breccia, and anastomosing shears with intervening deformed strata. Two west branches of the zone, the west branch fault and the Forster fault, lie about 2000 to 5500 feet west of the principal break in this area. The intervening area contains an undetermined number of interconnecting lesser unmapped faults. The complexity of this wide zone of faulting provides planes of weakness along which gravity failures can occur, and also provides avenues of entry for meteoric water. The contrast in resistance to weathering of fault juxtaposed units of the San Onofre Breccia, and the Topanga, Santiago, Monterey, and Capistrano Formations has resulted in the formation of a relatively high ridge of resistant San Onofre Breccia and Topanga Formation paralleling the fault zone. It is flanked by the less resistant Santiago Formation on the east and by the Capistrano and Monterey Formations on the west. This resistant highland tends to become oversteepened in some areas due to normal erosional processes. Such activity was probably heightened during the more pluvial epochs of glacial retreat. The continuing result of this oversteepening process is intermittent landsliding,especially where active stream cutting is operative and probably during moderate to large magnitude earthquakes. The latter is probably an important factor but difficult to assess locally without a large historic event on which to base judgment. Elsewhere large magnitude earthquakes have resulted in landsliding of great entent, i.e.,Alaska in 1964. It is therefore prudent to consider the possible effects of seismic shaking when considering slope stability.

Incidence of the larger landslides is greatest where stream activity has been greatest, i.e., where San Juan Creek and Cañada Chiquita drainages impinge upon the fault zone.

Of the formations occurring east of the fault zone, the Santiago Formation contains numerically and areally more landslides than the other formations present, although still amounting to no more than one and a half percent of the area. Most of the slides are less than ten acres in extent, appear to be dip controlled (Direction of failure coincident with dip), and show a slight preference for north-facing (Moisture-retaining) slopes. Controlling factors in remaining areas are similar with most of the slides being less than five acres in extent.

A more significant slope stability problem in the eastern part of the area is a propensity for mud-debris flows, notably in the Trabuco and Williams Formations. During periods of extended rainfall, such as during the 1969 floods, mud-debris flows emanating from the heads of steep canyons were a commonplace occurrence. Although most of these moved perhaps no more than 300 feet, they occurred very rapidly without warning and with great force. Furthermore debris from these flows may create problems in flood control channels.

These phenomena are difficult to portray on geologic maps because the features are small and evidence for them is very ephemeral. Virtually all of those shown on the map occurred during the storms of 1969, but earlier periods of intense rainfall almost certainly produced similar results. Once failure has taken place the potential for additional hazard is usually lessened; it is therefore important to predict factors which are conducive to their formation rather than depend upon the exact location of those shown on the map.

As already stated, terrain underlain by Trabuco and Williams Formations appears to be most susceptible to mud-debris flows. Although less common, such failures have been noted in the Santiago Formation, and in the Santiago Peak Volcanics. Failures occur mostly in accumulations of slopewash or colluvial debris which lies somewhat perched high and at the heads of narrow, steep drainage channels above alluvial valleys. When these materials become saturated they become mobilized en masse. The steeper and straighter the channel the farther the material can flow, picking up additional rock debris, mud, and vegetation, in the process. No structures should be built in the path of such channels without adequate diversion measures.

Other apparent slope stability problems are rock-fall and stream bluff failure. These also are most common during periods of extended rainfall and runoff. Rockfalls may occur wherever steep cliffs are present such as in Santiago Peak Volcanics, the Baker Canyon Member of the Ladd Formation and San Onofre Breccia. Bluff failures occur simply as a result of undermining of the bases of the bluffs by running water. Elementary as this may seem, this phenomenon is often overlooked in southern California because of the intermittent nature of its streams. Adequate setbacks and levees should be provided for structures built adjacent to stream-cut banks. This is especially important where the banks are composed of poorly consolidated Quaternary materials, such as alluvium, terrace materials, slopewash or fill.

In summary, slope stability problems in the south half of the Canada Gobernadora quadrangle are mainly (1) bedrock failures associated with the Cristianitos fault zone, (2) mud-debris flows in steep canyons of Trabuco and Williams Formation terrain, and (3) rock-fall along stream bluffs or steep cliffs.

MINERAL RESOURCE POTENTIAL

The mineral resource potential in the south half of the Canada Gobernadora quadrangle includes sand and gravel, specialty sands, riprap, clay, fill materials, and petroleum. The first three of these are presently being extracted in or adjacent to the area and the latter three have in some way been investigated or utilized.

Sand and Gravel

Sand and gravel has been mined from San Juan Creek deposits since 1964 by Consolidated Rock Products. The material consists of alluvial river deposits of late Holocene age and contains a gravel to sand ratio of about 60:40 where commercially developed (Goldman, 1968, p.40). The products produced include concrete aggregate, asphalt aggregate, aggregate base, and aggregate subbase. (See Quaternary alluvium for lithologic description.)

Areas of potential development exist both up and downstream from areas already mined. Additional potential deposits are considered here to be economically unfeasible to extract within the foreseeable future. These include conglomeratic units that are present in sufficient quantity to evaluate, i.e., river terrace deposits, Trabuco Formation, and conglomerate of the Baker Canyon Member of the Ladd Formation. The first two of these units contain excessive fines and furthermore the Trabuco Formation gravel contains a high percentage of unsound material. Conglomerate of the Baker Canyon Member contains well-cemented sandstone and clayey siltstone interbeds that would be costly to mine and wash.

Quaternary alluvial gravel deposits exist in Gabino, Verdugo, and Lucas Canyons,also but those canyons are rather narrow, and therefore contain very limited tonnages of workable material.

Specialty Sands

Owens-Illinois, Inc. began operation of a glass-sand deposit and mill south of Ortega Highway in Trampas Canyon in 1972. The deposit is developed in the lower beds of the Santiago Formation of Eocene age, and consists of massive to broadly crossbedded, medium- to coarse-grained, poorly sorted sandstone and grit containing interbeds of lenticular chlorite-rich siltsone.(See unit description.)

Extensive areas to the north of Ortega Highway, mapped herein as the lower member of the Santiago Formation are essentially the same in content, structure, and overburden ratios.

The chlorite-rich siltstone interbeds and resultant high iron content requires careful selective mining and together with the rather high minus 200-mesh fraction (as much as 20%) results in large volumes of wasted material.

At this writing, riprap is being quarried from andesite porphyry of the Santiago Peak Volcanics adjacent to Lucas Canyon in the northeast quarter of the quadrangle. Several hundred acres of similar material underlie the extreme northeast corner of the southeast quarter of the quadrangle.

Clay

Fire clay and china clay were mined from several small open pits and short adits driven into the Claymont Clay bed of the Silverado Formation both north and south of Ortega Highway, just west of the Mission Viejo Fault. These are denoted as prospects on the map. The operations have been inactive for several decades.

The clay horizon ranges in thickness from only three to six feet. Moreover, moderate dips and resultant high overburden ratios make the clay expensive to extract. It is not likely that these deposits will be economically workable within the near future. (See Silverado Formation in Appendix.)

Petroleum

Petroleum possibilities within the south half of the quadrangle have been explored by major oil companies. Deep wells and shallow test holes have been drilled as shown on the map. Although no production has been recorded from these wells, two abandoned oil fields (Cristianitos and San Clemente) a few miles to the south, have yielded some oil. Production was from the Schulz Ranch Member of the Williams Formation which is 1400 to 2000 feet thick within the area. (Gray, et al ,1971.)

The author believes that good possibilities for productive wells exist in this and adjacent areas from structural traps associated with the Mission Viejo and Cristianitos faults. Stratigraphic traps are a possibility within the Schulz Ranch Member of the Williams Formation because of the varied facies changes reflected in the lower siltstone, upper sandstones and conglomeratic sands, and the interfingering of fanglomeratic materials updip and laterally. A small oil seep was observed in a very limited exposure in the overlying Pleasants Sandstone Member along the Mission Viejo fault 1500 feet south of Ortega Highway. This suggests that conditions present in the San Clemente and Cristianitos fields may extend northward, and that this seep resulted from migration upward along the shear zone from the Schulz Ranch Member. Permeability of the Pleasants Sandstone Member is low.

Fill Materials

The wide variety of lithologic types and rock units exposed in this area offers abundant sources of fill materials for construction use. Of special note is the extensive and uniform expanse of massive, friable, well-graded sandstone of the lower beds of the Santiago Formation between Cañada Chiquita and Bell Canyons.

APPENDIX

DESCRIPTIONS OF GEOLOGIC UNITS

The descriptions that follow are arranged in the order of geologic age with the youngest units described first. Letter symbols correspond to those found on the geologic map. Color designations are from the Geological Society of America Rock Color Chart. (Goddard et al.,1951.)

Following the physical descriptions and discussion of age relationships, are the pertinent engineering and environmental geologic factors characteristic of the unit. These include such things as slope stability, susceptibility to erosion, permeability, degree of difficulty to excavate, and use potential.

SURFICIAL UNITS

$Qal_{1,2}$

Alluvium. Holocene Age. Alluvium of active stream channels. Widely variable composition because of diverse source areas. Generally yellow-gray (5 YR. 8/1) to light-gray, (N7), unconsolidated, fine to coarse, poorly sorted, angular, permeable sand and gravel. Designated Qal where undifferentiated; Qalb where boulder content is very high.

Qal_1 and Qal_2 are essentially the same materials, but Qal_2 represents the most recently active channels that are affected annually by alluvial processes. Qal_1 represents materials deposited during a previous cycle, possibly with different climatic conditions. Qal_1 is exposed along the banks and adjacent to the active channels, but also underlies Qal_2. Typically, a thin mantle of soil, as much as 12 inches thick, has developed on Qal_1 exposed surfaces.

In San Juan Canyon Qal_1 and Qal_2 are composed of beds of medium to coarse sand and gravel that are massive to crossbedded, unconsolidated, subangular, poorly sorted (well graded) quartzo-feldspathic lithic sand. Clasts are predominantly "eastern bedrock complex" materials, with metasediments of the Bedford Canyon Formation predominant over metavolcanics and granodiorite. Clast size ranges from 1/2" to 3" in the western part of the quadrangle where there is a gravel to sand ratio of about 60:40 (Goldman, 1968, p. 40). Size range is quite variable at depth. Subsurface data indicate fine-grained sediments below 70 feet (Qoal?) and a total depth of as much as 210 feet to bedrock near the gauging station near the west boundary of the area. Channel width exceeds 2000 feet (Channel depths and widths include Qal through Qoal materials.)

Deposits in Bell, Lucas, Verdugo, Gabino, and La Paz Canyons are quite similar to materials described for San Juan Canyon except for size ratios, size ranges, and channel dimensions. Generally the gravel to sand ratios and size range of clasts is greater, while channel widths are smaller by a factor greater than two.

$Qal_{1,2}$ in Cañada Gobernadora and Cañada Chiquita are less coarse than in San Juan Canyon and Bell Canyon. Surficial exposures and water well logs indicate mostly sand and clayey sand and minor gravel lenses. In general a gravel zone is reported to occur near the base of the alluvial section (including Qoal.) Subsurface data suggest that bedrock depth may be as much as 125 feet in the lower reaches (Meidav, 1969.)

Quaternary alluvium is generally well suited for pervious fill and aggregate,but clasts are rather coarse except in San Juan Creek, Cañada Gobernadora, and Cañada Chiquita. Perennial ground water underflow of potable quality is present in the major canyons. Poorly suited for most solid waste disposal sites because of high permeability. Rippability 4.

Qsw
Slopewash. Holocene Age. Detrital materials resulting from gradual downslope transport largely under the influence of gravity but aided by rill wash, ground water, and unchanneled surface drainage. Generally accumulates at or near the base of slopes and at the mouths of canyons. Includes colluvium, minor residual soils, and alluvium, especially where these materials are transitional with slopewash or are otherwise indistinguishable. Mapped only where judged to exceed three feet in thickness. Composition varies widely with parent materials but in general consists of dark-brown to nearly black, clayey, organic-rich, structureless material, plastic when wet,and hard and brittle when dry; contains variable proportions of sand and fragments of bedrock. Designated Qswb where boulders predominate. (See rock units for physical characteristics of slopewash derived from each.)

Slopewash is particularly susceptible to slump, creep, and mudflow; is generally moderately permeable, poorly consolidated, of low density, highly erodible, and commonly contains expansive montmorillonite clay (Qswe where noted.) Generally poorly suited for shallow fills unless blended with coarser materials. Possibly suited for topsoil if stockpiled during grading for housing developments. Rippability 4.

Qls
Landslide debris. Holocene to Pleistocene age. Generally unconsolidated, incoherent, chaotic, unsorted, angular, pervious debris, commonly containing large boulders where derived from well consolidated materials. Commonly indiscernible from parent rocks, where these are fine-grained and structureless, except by geomorphic features common to landslides. Large coherent block-glide types of slides distinguished only by anomalous bedding orientation, structural position, topographic features, and presence of slide plane at base. Landslide terrain typified by hummocky, subdued topography beneath an arcuate crown area marked by an abrupt rise in slope angle; toe area often crowds, diverts or blocks drainage and commonly is the site of seeps or springs; more recent slides commonly contain a complex network of internal subsurface drainage channels. Large slides commonly exhibit an irregular drainage pattern and a more youthful landscape than surrounding areas; commonly contain undrained depressions. Drainage area below landslides commonly choked with slopewash originating from slide.

Prone to creep, slump, mudflow, and renewed mass movement, especially where loaded by fill or water influx, or where undermined by erosion or excavation. Crown area above slide commonly oversteepened and prone to collapse, effecting additional sliding. Variable suitability for fill depending upon source rock. Commonly highly permeable with springs or seeps occurring near the toe. Very susceptible to erosion. Large slides may be suitable for Class II and Class III waste disposal sites if carefully controlled. Rippability 4 to 3.

Qps
Perched soil. Holocene to Pleistocene age. Residual soils and colluvium occurring largely on summits or gently undulating elevated areas. In part, thought to represent erosional remnants of soil developed prior to the last general uplift. Mapped only where judged to exceed three feet in thickness. Composition widely variable, reflecting the nature of underlying parent rock, but generally similar to slopewash. Commonly contains expansive montmorillonite clay (Qps where noted.) Suitability for fill varies with parent materials. Rippability 4.

Qoal
Older alluvium. Holocene to Pleistocene Age. Oldest alluvial unit occupying the margins of present-day alluvial channels. Widely variable composition because of diverse source areas. Generally yellow-gray (5 YR 8/1) to light-gray (N7) coarse- to fine-grained, unconsolidated, interbedded, cross-bedded, angular, permeable sand, silty sand, clayey sand, and minor gravel. Highly lenticular, discontinuous beds.

Underlies Qal$_{1,2}$ but discernible from it on the surface only where Qoal underlies elevated terrace surfaces and by development on it of thick soil. Areas underlain by Qoal commonly are prime areas for cultivation. In Cañada Gobernadora and Cañada Chiquita Qoal is closely associated with lake beds (?) mapped separately as Ql where discernible. The alluvial section in Cañada Gobernadora and Cañada Chiquita, including Qal$_{1,2}$ Qoal, and Ql, is as much as 125 feet thick (Meidav, 1969.)

Qoal has moderate permeability, is highly erodible, and is well suited for fill. A paucity of gravel in most areas, except in San Juan Creek, precludes use as aggregate. Poorly suited for waste disposal because of high permeability. Rippability 4.

Ql
Lake or pond deposits. Holocene to Pleistocene age. Thought to be sediments deposited in temporary lakes formed possibly as the result of landslide obstructed drainage, or possibly representing sluggish meandering stream deposits. White to gray-brown (5YR 5/1), weakly consolidated, flat-lying, thin, well-bedded to massive to weakly crossbedded, fine- to coarse-grained, fairly well sorted, angular, organic-rich, dark, sandy clay alternating and grading to gray, clayey sand reflecting cyclic deposition. Clots of caliche to one centimeter in diameter reflect weak carbonate cementation and periodic desiccation. Locally contains small thin-shelled, fresh water pelecypods, (Physa sp., Goniobasis sp.)

As much as twenty-five feet thick. Closely associated with Qoal and underlies $\text{Qal}_{1,2}$ and Qsw. Younger than Qtr, Qt.

Low permeability creates a perched water table and resultant springs and seeps where overlain by permeable materials, especially along the margins of Cañada Chiquita and Cañada Gobernadora. Also gives rise to heavy runoff during major storms. Low permeability also may limit use as fill material and hamper effectiveness of dissipating cesspools or other effluents. Rippability 3.

River Terrace Deposits

Qtr_4
Fourth deposited of four river terraces of the San Juan-Bell Canyon drainage.

Pleistocene age. Thirty to 40 feet of reddish-brown (10R-5/4) poorly to fairly well indurated, poorly bedded, very coarse, poorly sorted conglomerate. Clast sizes range from boulders two feet in diameter to small pebbles, but average four to six inches in greatest dimension. Larger clasts generally are rounded to sub-rounded quartz diorite and granodiorite; smaller clasts are predominantly metamorphic rocks and tend to be subangular. Rock types in order of abundance, without regard to clast size, are metavolcanic rocks of the Santiago Peak Volcanics, metasedimentary rocks of the Bedford Canyon Formation, plutonic rocks of the Peninsular Ranges, sandstone, and gneiss. The matrix is reddish, earthy, poorly sorted, sandy silt.

Qtr_4 lies at elevations between 20 and 120 feet above present river grade. It forms wide, flat, well preserved terraces as much as 2000 feet wide normal to the drainage and is as much as 40 feet thick.

Even though not well cemented, it forms very stable erosion-resistant slopes. It stands in bluff-flanked, mesa-like forms, and is capped by one to two feet of clayey loam soil and yields a cobbly, clayey-silt slopewash that commonly mantles the base and face of the flanking bluffs. Susceptible to rock-fall adjacent to steep cut-banks of active streams. Moderately low permeability.

Generally suitable for some fill use, but boulders may pose disposal problems. Not well suited as an aggregate source because of excessive fines in matrix and weathered condition of clasts. Rippability 3.

Qtr$_3$

Third deposited of four river terraces of the San Juan-Bell Canyon drainage. Pleistocene age. Composition and general character of Qtr$_3$ are similar to Qtr$_4$ except for notably larger clast sizes and a greater abundance of boulders of metamorphic rocks.

Qtr$_3$ lies generally between elevations of 100 and 200 feet above present river grade. It occurs in mesa-like erosional remnants as wide as 1500 feet normal to the drainage and is as much as 30 feet thick. (See Qtr$_4$.)

Qtr$_2$

Second deposited of four river terraces of the San Juan-Bell Canyon drainage. Pleistocene age. Composition and general character closely similar to that described for Qtr$_4$ above. Lies between elevations of 120 and 280 feet above present river grade in erosional remnants as wide as 1000 feet normal to the drainage, and as much as 40 feet thick. (See Qtr$_4$.)

Qtr$_1$

First deposited of four river terraces of the San Juan-Bell Canyon drainage. Pleistocene age. Reddish-brown, moderately well indurated, poorly bedded, poorly sorted conglomerate. Sixty to 75 percent of the clasts are composed of subrounded granodiorite and tonalite that range in size from pebbles to boulders, but which average six to ten inches across. The remaining clasts are composed of subangular metavolcanic and metasedimentary rocks most of which are pebble size. The matrix is very coarse, poorly sorted, fairly well-cemented sand and grit.

Qtr$_1$ crops out in small, isolated, resistant erosional remnants as much as 40 feet thick at elevations of 300 to 380 feet above present river grade. Rippability 2. (See Qtr$_4$.)

Qt

River terrace deposits, undifferentiated. Pleistocene age. Generally coarse, unconsolidated, poorly bedded, poorly sorted, rounded cobble gravels occurring in irregular erosional remnants flanking the major canyons tributary to the main San Juan-Bell Canyon drainage and along Gabino and La Paz Canyons. Composition and general character similar to Qtr$_4$ above.

Generally less than 20 feet thick. Probably contemporaneous to Qtr$_{1-4}$. Rippability 3. (See Qtr$_4$.)

Qc

Nonmarine sand (older slopewash?) Pleistocene age (?). Very light-gray, (N8) massive, clayey to silty, poorly sorted, angular, sandstone. It is moderately impermeable, poorly consolidated, and of low density. Contains sparse fibrous carbon fragments suggestive of grasses.

Expressed in terrace-like thin remnants near the heads of canyons and marginal to existing drainages. Suggesting that these are remnants of older slopewash. Flatly and unconformably overlying Tertiary units in thicknesses generally less than twenty feet. Sparse, low chaparral and grasses are typical vegetational cover.

Fairly stable but plastic when wet and easily eroded into badland-like forms. Moderately low expansivity. Limited use as fill because of thinness and minor distribution. Yields very little clayey slopewash. Rippability 4; may mire equipment when wet.

BEDROCK UNITS

Tc

Capistrano Formation. Late Miocene to early Pliocene age. Marine, yellow-gray (5YR 7/2) to light-brownish-gray (5YR 6/1), poorly bedded to massive and, locally well-bedded, moderately hard if dry, to very soft when wet, porous, biotite-rich siltstone, clayey siltstone, and sandy siltstone with one to two-foot thick interbeds of hard silty limestone and minor medium-gray, medium-grained, massive, hard, thin, moderately well sorted, angular, sandstone. Contains abundant secondary gypsum along joints, bedding, and fractures.

Overlies Monterey Formation gradationally and is overlain west of the area by Niguel Formation. Grades laterally into Oso sandstone Member northwest of the area. Contains sparse upper Mohnian foraminifera in transitional zone with underlying Monterey Formation (Smith, 1960, p. 473.) Top not exposed in quadrangle, but unit is as much as 2100 feet thick a few miles to the west.

Capistrano terrain is moderately steep and rounded with poor exposures but commonly with sharply incised canyon bottoms. Natural cover is mainly grasses with light brush.

Inherently weak and unstable; subject to creep, mudflow, and massive failures when under heavy moisture conditions; very low shear strength when saturated. Very low permeability and high porosity. Heavy runoff factor. Highly expansive; clay fraction has high montmorillonite content. Highly jointed; bedding is secondary in prominence. Erodibility fair; slopes exceeding 27° ravel continuously. Sulfate content high. Suitable for impermeable fill but commonly expansible. Possibly suited for Class II and Class III solid waste disposal sites. Ubiquitous two-foot soil cover on most slopes. Yields moderate amounts of expansive clayey slopewash. Rippability 4;equipment mires if saturated.

Tm

Monterey Formation. Late Miocene age. Marine, white to yellowish-gray (5YR 8/1) and light-brownish-gray (5YR G1), very well bedded, thinly-bedded, fissile, soft, tuffaceous and diatomaceous siltstone and shale, also one- to two-foot interbeds of very light-gray (N8) limestone.

Rests unconformably on San Onofre Breccia and Topanga Formation. Overlain by Capistrano Formation with gradational contact. Contains abundant upper Mohnian foraminifera and reportedly Luisian forms at depth (Smith, 1960, p. 472.) Thickness reaches 1200 to 1500 feet just west of the quadrangle.

Monterey terrain is characterized by well rounded, subdued, rolling topography with generally poor exposures and a ubiquitous two-foot black, clayey soil cover. Vegetational cover is predominantly grass with light brush and cacti.

Very unstable. Abundant bedrock and surficial failures. Inherent weakness due to high fissility, abundant joints, high porosity, high plasticity when wet, and presence of bentonitic layers. Moderately low erodibility. Permeability is low except in near-surface weathered zone which is pervious due to fractured nature. Heavy run-off factor. Suitable for Class II and Class III solid waste disposal sites due to ease of excavation and low permeability. Very low density-high porosity materials possibly suitable for light-weight expanded aggregate or as an absorbent. Poor for most fill use due to difficulties in compaction, its expansive nature, high plasticity, and low density. Yields moderate amounts of highly plastic, expansive clayey slopewash. Rippability 4; mires equipment when saturated.

Tt
Ttso
Topanga Formation and San Onofre Breccia. Middle Miocene age. Tt-Topanga Formation. Interbedded marine, light-gray (N7) to grayish-yellow (5YR 8/4), well cemented, moderately well bedded, coarse- to medium-grained, poorly sorted, angular, calcareous sandstone and conglomeratic pebble sandstone; and lenticular grayish-yellow to light-gray, friable, fairly well bedded, fine- to coarse-grained, moderately well sorted to poorly sorted, angular,sandstone. Pebble clasts are composed predominantly of San Onofre-type of debris (See Ttso below.) Lenticular grayish-yellow (5YR 8/4), massive to poorly bedded siltstone (Tts.) Highly fossiliferous; contains middle Miocene fauna including Turritella ocoyana Conrad, Pecten andersoni Arnold, Pecten cf. Vanvlecki Arnold, Pecten crassicardo clementia sp., Lyropecten (Amusium) lompocensis, Arnold.

Ttso - San Onofre Breccia. Light-gray (N7) to reddish-brown (10R, 5/4), well cemented to poorly cemented, massive to poorly bedded, very coarse, extremely poorly-sorted, angular breccia; interbedded lenticular light-gray to yellow-gray (5 YR 7/2), well cemented, well- to poorly bedded, poorly sorted, coarse pebbly sand, grit, and silt, all of which grade abruptly into each other or into the breccia facies.

Angular clasts range in size from small pebbles to blocks as much as 15 feet in maximum dimension composed mostly of quartz sericite schist, amphibole schist, albite quartz schist, glancophane schist, blue and green schists, and saussuritized gabbro.(Woodford, 1925, p. 200-202.) The matrices are either reddish-brown to light gray, earthy, poorly cemented, silty material reflecting the mineralogy of the clasts or light-gray, well cemented, poorly sorted, angular sand composed mostly of quartz, feldspar, and lithic grains.

Although San Onofre Breccia generally overlies Topanga Formation in most areas, they are intricately interfingered and interbedded in this area; abrupt transition from one to the other is common. Topanga Formation-San Onofre Breccia lies with gradational contact on the underlying Vaqueros Formation and is overlain with apparent unconformity by the Monterey Formation. In exposures in the north half of the quadrangle Topanga Formation is less than 400 feet thick but is reported 7000 feet thick in the San Joaquin Hills and 2500 feet thick in the northern Santa Ana Mountains (Yerkes, et. al, 1965, p. A32.) Topanga Formation-San Onofre Breccia terrain is characterized by sharp, rugged topography, commonly with steep cliffs. Abundant low, thick brush and cacti dominate the vegetational cover.

Both the San Onofre Breccia and Topanga Formation are generally stable and resistant to erosion, but steep cliffs are subject to sudden minor rock falls. Moderately impermeable except in the less common friable beds. Caution should be exercised in making steep excavations at or near interfaces between well- and poorly cemented beds or where interbedded siltstones are present. Variable suitability for fill use; large boulders may present disposal problems. Some, however, are useful for landscaping. Possibly suitable for Class II and Class III waste disposal sites but may be difficult to excavate locally, and may require permeability barriers for Class II waste.

Although generally resistant and stable, the San Onofre Breccia is involved in a large number of landslides of great extent. This is probably due to the breccia's distribution adjacent to the Cristianitos fault zone.(See Slope Stability Summary.) Tt and Ttso yield sand, nonexpansible slopewash which is dissipated rapidly by erosion. Tts yields highly expansible slopewash. Rippability 2-3.

Ts
Sespe Formation. Late Eocene to Early Miocene age. Very light-gray (N8) to pale-yellowish-gray (5YR 8/1.) Predominantly nonmarine (?), conglomeratic, coarse sandstone. Poorly to well bedded, massive in basal beds, poorly indurated, friable, coarse- to medium-grained, poorly sorted, subrounded to subangular grains with abundant lithic fragments: locally rich in biotite. Contains minor thin interbeds of brown (5YR 5/2), reddish-brown (10R 5/4), and greenish-gray (5 GY 6/1) siltstone, clayey siltstone, and sandy siltstone. Individual beds range in thickness from 5 to 25 feet.

The Sespe Formation rests with gradational contact on the Santiago Formation, of Eocene age. In this quadrangle, it is overlain with apparent unconformity by the Vaqueros Formation of early Miocene age and attains a thickness of about 1500 feet. It has been reported to be as thick as 2450 feet in the San Joaquin Hills. (Yerkes, et al., 1965, p.A30.)

Sespe terrain in this area, unlike areas north and northeast of the quadrangle, is characterized by moderately steep, but rounded, cobble-strewn slopes and sparse, low scrubby vegetation and grass. Natural exposures are generally poor except for a few relatively resistant conglomerate beds near the base of the section that tend to form cliffs.

Gross slope stability characteristics are apparently good, as relatively few landslides occur in the area. Erodibility, and permeability are high to moderate because of the extremely friable, granular nature of the material. Low expansivity. Joints and bedding are of subordinate importance to slope stability because of the low cohesive strength of most of the rocks. Suitable for pervious fill though may be difficult to compact locally unless blended. A possible ground water aquifer. Potentially useful north of this half of the quadrangle as a source of aggregate but sand fraction is generally high. Suitable only for Class III waste disposal sites due to high permeability. Yields sandy, cobbly slopewash that intergrades rapidly to stream channels. Rippability 4.

Tsau
Tsal
Santiago Formation. Eocene age. Tsau-upper beds. Interbedded marine, grayish-yellow (5YR 7/5) to white, friable, poorly bedded, medium- to fine-grained, well to poorly sorted, angular to subangular, sandstone, and reddish-brown (10R 4/4) and greenish-gray (5GY 6/1) variegated sandy siltstone and claystone. Contains Ostrea stewartii at one locality south of the quadrangle boundary, which may indicate that this member is correlative with marine Eocene units of the San Diego area.

In gradational contact with overlying Sespe Formation and underlying lower member. Apparent thickness of as much as 1200 feet. Terrain is rounded and subdued with very poor exposures because of a clayey soil residue, one to two feet thick. Sparse, low chaparral and grass cover the area.

Moderately stable but easily eroded, and yields thick, expansive slopewash and residual soil. Moderate expansivity. Ground water movement erratic and subject to lateral flow along interfaces between thinly interbedded impermeable clay and permeable sand. Variable suitability for fill use. May be suitable for Class II and Class III waste disposal if permeability is controlled. Rippability 4 to 3; clay beds and soil mires equipment when wet.

Tsal - lower beds. Marine (?), very light-gray (N8) to yellowish-gray (5YR 8/1), friable, massive to broadly crossbedded, medium- to coarse-grained, poorly sorted, angular, moderately permeable sandstone and grit composed of nearly equal parts of quartz and feldspar with minor biotite becoming more abundant towards the top. Contains variable amounts of greenish-gray (5GY 6/1) clay occurring as a matix in the sandstone and in thin lenticular bodies a few tens of feet in lateral extent; lenticular chloritic siltstone; scattered conglomeratic lenses with predominant granodiorite and quartz diorite cobbles and pebbles especially near base; and scattered angular blocks and logs of closely-grained silicified wood.

Overlies the Silverado Formation of Paleocene age with pronounced unconformity in this area and grades into the upper beds of the Santiago Formation. Minimum estimated thickness, 2000 feet.

Moderately well exposed in grossly gentle, undulating terrain; locally low cliffs and steep canyon walls are common. Santiago terrain (lower beds) supports heavy chaparral on slopes and abundant large live oak and sycamore trees in the valleys.

Apparently stable and fairly resistant to erosion. Low expansivity. Yields a clayey-sand slopewash which accumulates in thick, permeable, lobate masses. Generally suited for fill use because of well graded, friable nature. Suitable only for Class III waste disposal because of permeability. Present source of glass sand; percentage of fines and chloritic lenses may make it undesirable locally. Rippability 3.

Tsi

Silverado Formation. Paleocene age. Interbedded, nonmarine, extremely varied beds consisting of a basal pale reddish-brown, (10R 5/4) to light-gray (N7), massive, moderately well consolidated, rounded cobble conglomerate (Tsic), pale-reddish-brown, moderately well to poorly indurated, well bedded, poorly to fairly well sorted, angular, pervious anauxite-and biotite-rich sandstone, pebble conglomerate, grit, varicolored siltstone and a distinctive variegated reddish-white, and yellowish pisolitic clay bed (Claymont Clay Bed of Woodring and Popenoe, 1945) that lies 150-250 feet above the base of the formation. The Claymont Clay Bed in Bell Canyon consists of six feet of highly altered pisolitic sandy kaolinite claystone (designated by mappable bed symbol-C-on map.) The pisolites range from 1/8 inch to one inch in diameter and occur as close as 1/4 inch to 3/4 inch centers. Individual pisolites are composed of iron-stained clots of quartz grains with a minor clayey matrix. Sand grains in the bed are almost angular quartz. Although not observed in the mapped area, thin interbeds of lignite and carbonaceous silt are common in areas to the south and northwest and may be present locally. Basal conglomerate locally absent.

Silverado terrain characterized by subdued topography of variegated reddish colors and rather sparse vegetational cover. Unconformably overlies Cretaceous rocks of the Williams Formation and is only a few hundred feet thick. Silverado strata are separated from the overlying Santiago Formation in this quadrangle by a pronounced unconformity.

Apparently very stable, but poorly resistant to erosion. Yields sandy silt slopewash which disperses rapidly. Variable permeability but generally low. Variable suitability for fill use. Possibly suited for Class II and III waste disposal except for more permeable conglomerate. Claymont Clay Bed and other clay beds have been mined for fire clay, china clay and as cement additives. Rippability 2-3.

Kw

Williams Formation. Late Cretaceous age. Kwp - Pleasants Sandstone Member. Marine, pale-olive-gray (5YR 7/1) to pale-yellow-brown (1SYR 7/2), medium- to fine-grained, well sorted, friable, angular, poorly bedded, biotite-rich sandstone, and interbedded light-gray to yellow-gray (5YR 8/1) poorly cemented, massive, porous, siltstone and pale-yellow-brown, concretionary, medium-grained, well sorted, biotite-rich, fossilferous sandstone.

Overlies and grades into the Schulz Ranch Member of the Williams Formation. Unconformably overlain by the Silverado Formation. Contains sparse Late Cretaceous fauna. Kwp is 1300 feet thick in a drill hole east of Cañada Gobernadora. Pleasants terrain is characterized by moderately steep, brushy slopes with generally poor exposures.

Apparent slope stability good, though moderately easily eroded and prone to shallow mudflows at the heads of steep canyons during periods of heavy rainfall. Variable permeability but generally low. Yields a slight residual soil and moderate amounts of slopewash which disperses rapidly. Generally suitable for slightly permeable fill and adaptable for Class II and Class III waste disposal sites. Concretionary beds yield moderate amounts of hard calcareous boulders ranging from six inches to two feet in diameter.

Kws

Schulz Ranch Member* - Upper beds (Kwsu) Gray-white, coarse to fine-grained, finely bedded to massive, poorly to moderately well consolidated, generally poorly sorted, permeable, feldspathic and biotite- rich conglomeratic sandstone. Well rounded clasts range in size from small pebbles to cobble-size and are composed predominantly of granodiorite with lesser amounts of fine-grained dark metasedimentary and metavolcanic rocks. Grades downward into light-olive-gray (5YR 6/1) siltstone (Kwsl) which is moderately well bedded, moderately well consolidated and relatively impervious. These lower beds are underlain and interfinger with grayish-yellow (5YR 8/4) poorly bedded, moderately well to poorly sorted, silty conglomerate and very coarse-cobble fanglomerate (Ksw$_2$.) Northward this conglomerate-fanglomerate interfingers with the upper beds (Kwsu) and southward lenses out. The only fossils noted in the Williams Formation were palm fronds, other unidentified leaf casts, and sparse chips of petrified wood which were found mostly in Kwsl.

Rests with apparent unconformity on the Ladd Formation and grades upward into the Pleasants Sandstone Member. Overlaps Ladd Formation in southern areas. Schulz Ranch Member attains a thickness of at least 1400 feet and possibly as much as 2000 feet in the quadrangle. Kws$_2$ attains a maximum thickness of about 600 feet and Kwsl may be as much as 1000 feet thick.

*Used in place of Schulz Ranch Sandstone Member because of wide variation in this area of rock types included.

Schulz Ranch Member terrain is characterized by moderately well exposed, sharply incised steep topography with dense chaparral cover in its upper part, and moderately steep, but rounded, poorly exposed terrain with moderate brush in lower beds.

Apparently good slope stability but erodes easily and has a high propensity for shallow mudflows at the heads of steeper canyons during periods of extended rainfall. Moderately permeable in upper beds; less so in lower silty beds.

Yields loose sandy to silty slopewash; sandy slopewash tends to disperse readily in stream channels while silty areas of Kwsl tend to build up aprons at the base of slopes. Kwsu suitable for permeable fill; Kwsl and Kws$_2$ for moderately impermeable fill. Kwsl and Kws$_2$ suitable for Class II and Class III waste disposal sites. Remainder suitable only for Class III sites. Rippability 4.

Kl

Ladd Formation. Late Cretaceous age. *Klh-Holz Shale Member*. Marine, soft, light-olive-gray (5YR 6/1) to gray-green (5GY 6/1), silty, poorly bedded shale and interbedded minor lenses of conglomeratic limestone, bituminous sandstone, and coquina. Contains Campanian fauna including *Nanonavis brewerianus* (Gabb), *Biplica obliqua* (Gabb), *Turritella chicoensis* (Gabb), *Baculites* sp., *Lima* sp.

Holz Shale Member rests unconformably on, interfingers with, and grades downward into the Baker Canyon Member. Wide variation in thickness, suggesting abrupt facies changes and complex interfingering relationships within the Ladd Formation. May reach as much as 800 feet in thickness in the north half of the quadrangle and is reported to be 1500 feet thick in the northern Santa Ana Mountains (Popenoe, 1942, p. 171.)

Holz Shale Member terrain is typified by rounded and subdued topography supporting grass and low sparse brush. Natural exposures are rare because of clayey colluvium and soil mantle. Broadly spaced irregular drainage pattern contrasts markedly with overlying Williams Formation and the underlying Baker Canyon Member.

Softness, irregular bedding plane fractures and joints, high porosity, moderate expansibility, and pore-water retention characteristics, make Holz Shale Member susceptible to slump-type slope failures of moderately large extent. Landslides encompassing as much as 70 acres are present in the north half of the quadrangle; however in the south half, ten acres is the largest mapped. Shallow subsurface erosion pipes, one to two feet in diameter, are common in some areas. Low permeability. Expansivity and impervious nature limits use as fill. Well suited for Class II and Class III waste disposal sites. Yields clayey to silty soil and slopewash mantle. Mires equipment when wet. Rippability 4-3.

Klb

Baker Canyon Member* - Marine, interbedded, light-gray (N7) to yellowish-gray (5YR 8/2), well bedded, well indurated, calcareous, medium- to coarse-grained, moderately well sorted, highly fossiliferous sandstone and conglomeratic sandstone containing well rounded pebble to cobble-sized clasts of metavolcanic and metasedimentary rocks, and plutonic rocks of intermediate composition. Basal conglomerate (Klbc) is well indurated, pale yellowish-brown (10YR 7/2) to light gray (N7), massive to well bedded and contains well rounded clasts of fresh granodiorite, tonalite, metavolcanic, and metasedimentary rocks in a well indurated to moderately well indurated matrix of gray, poorly sorted coarse-grained lithic sandstone. In some areas the conglomerate is interbedded with three- to six-inch beds of yellow-gray (5YR 7.2) silty shale which also contain pebble to cobble-sized clasts. Sandstone contains abundant Turonian fauna including Calva cf. C. regina Popenoe, Glycymeris cf. G. pacificus (Anderson), Liopistha sp., Acteonella oviformis Gabb, Trigonarca californica Packard, Glycymeris veatchii (Gabb), and Coralliochama sp.

The basal conglomerate (Klbc) of the Baker Canyon Member rests with probable unconformity on conglomerate of the Trabuco Formation, although this relationship is not readily apparent in the field; the contact may be gradational as only transitional zones were observed. In some areas the basal unit is either missing or is so similar to Trabuco Formation as to be indistinguishable from it. Contacts with overlying Holz Shale Member are equally unclear, but outcrop patterns suggest that the units interfinger laterally and are transitional vertically. The Baker Canyon Member is as much as 500 feet thick in the quadrangle and has been reported to be as much as 650 feet thick in the northeastern Santa Ana Mountains (Popenoe, 1942, p. 177.)

Baker Canyon Member terrain is typified by bold outcrops. Basal conglomerate and calcareous members tend to form cliffs as much as 30 feet high. Except for cliff faces, the member supports dense growths of brush.

Slope stability excellent except where transitional to Holz Shale Member. Moderate to low permeability. Very resistant to erosion. Poorly suited for fill and waste disposal because of very hard blocky interbeds. Yields scant, sandy and cobbly slopewash which disperses rapidly into drainages. Rippability 2 to 3.

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*Used in place of Baker Canyon Conglomerate Member because conglomerate is not predominant in this area.

Kt
Trabuco Formation. Late Cretaceous age. Nonmarine, variegated reddish-brown (10R 5/4) to pale-red-purple (5RP 6/2) to light brownish-gray (5YR 7/1), massive, poorly indurated, unsorted, permeable, deeply weathered conglomerate. Well rounded clasts range in size from small pebbles to boulders three feet or more in diameter consisting mostly of andesite, tonalite, granodiorite and metasedimentary and metavolcanic rocks derived from the Santiago Peak Volcanics and the Bedford Canyon Formation. Many clasts are highly weathered and disintegrate readily, especially the tonalite and granodiorite. The matrix is a variable soft, unsorted mixture of earthy sand and silt with abundant lithic fragments derived from the Santiago Peak Volcanics and the Bedford Canyon Formation.

Trabuco conglomerate lies with distinct, often irregular, unconformity on Santiago Peak Volcanics. It is overlain unconformably or grades up into the Baker Canyon Member of the Ladd Formation. It attains a maximum estimated thickness of about 2000 feet between Lucas and Verdugo Canyons.

Terrain underlain by Trabuco Formation is rather sharply incised but rounded in detail, and exposures are poor. The drainage pattern has developed into broadly spaced canyons with uniformly dendritic tributaries. Vegetational cover consists of moderately dense brush to highly dense chaparral.

Generally stable but easily eroded and strongly inclined to debris flows from the heads of steep draws and canyons during periods of heavy rainfall. Moderately permeable and lacks structural fabric. Possibly suitable for pervious fill but boulders may be objectionable. Probably suitable only for Class III waste disposal. Yields abundant cobbly, bouldery, sandy slopewash which thinly mantles most areas and forms thick fans and aprons. Rippability 4.

Jsv
Santiago Peak Volcanics. Jurassic age. Complex sequence of mildly metamorphosed volcanic flows, dikes, pyroclastic rocks, and interbedded sediments. Most are dark gray to greenish gray (5GY 5/1), fine grained, often porphyritic, dense, highly jointed and sheeted, and moderately impervious. Includes andesite, felsic tuffs, argillite, and metasandstone. Intrudes and overlies Bedford Canyon Formation unconformably north and east of area. Intruded by granodiorite and tonalite north and east of area; separated from overlying Cretaceous section by pronounced unconformity.

Rather poorly exposed in steep, sharply incised terrain covered by dense chaparral. Commonly mantled by soil cover containing abundant small angular rock debris. Thickness not determermined because of irregular attitudes, faulting, and poor exposures, but described previously by Larsen (1948, p. 23) as possibly "thousands" of feet thick in the Santa Ana Mountains in general.

Generally stable but yields abundant slopewash debris consisting of angular chips in a clayey matrix. These accumulations may form dangerous mudflows during prolonged rainy periods especially in steep narrow arroyos. Moderately well suited for small riprap or crushed-type fill, but requires blasting. Difficulty in excavation limits use for waste disposal except for Class III; too fractured for Class I. Some areas in the Santa Ana Mountains contain highly irregular, discontinuous pod-like bodies of lead-zinc, copper, and gold ores. These have proved thus far to be difficult to explore and develop economically. Very low permeability. Rippability 2 to 1.

SCALE OF RIPPABILITY USED IN DESCRIPTIONS*

1. Very hard to hard. Blasting necessary to probably necessary.
2. Hard to moderately hard. Blasting probably necessary, to rippable with difficulty.
3. Moderately hard to firm. Rippable with difficulty to easily ripped.
4. Firm to soft. Easily ripped to easily cut.

*under normal moisture conditions

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TOPOGRAPHIC BASE BY U.S. GEOLOGICAL SURVEY
This map is an enlargement of a 1:24,000-scale published map

GEOLOGIC MAP OF THE S 1/2 CAÑADA GOBERNADORA QUADRANGLE, ORANGE COUNTY, CALIFORNIA

By Paul K. Morton

1974

Mapping Completed: SW 1/4 1966-67 SE 1/4 1969-70
Drafted by Betty Lindgren

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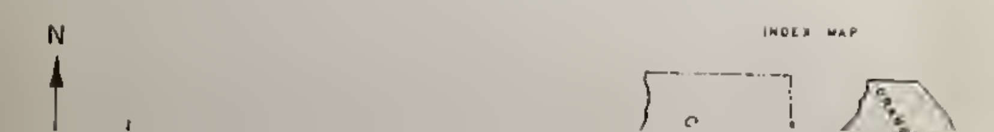

EXPLANATION

TOPOGRAPHIC BASE BY U.S. GEOLOGICAL SURVEY
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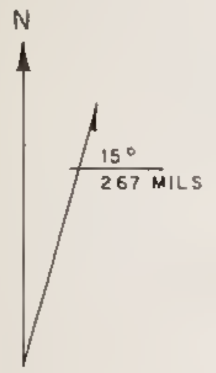
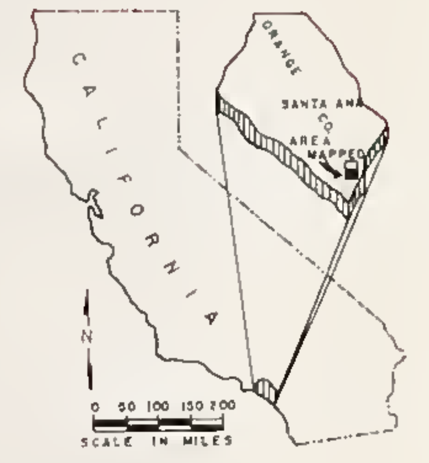


INDEX MAP



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EXPLANATION

QUATERNARY	Holocene	al	Artificial fill
		Qal, Qalb, Qal2, Qal1	Alluvium, undifferentiated, Qalb, where boulders predominate, subscripts denote order of deposition
		Qsw, Qswb, Qswe	Slopewash debris, Qswb, where boulders predominate; Qswe, where noted to be expansive
		Qls, Qls(?)	Landslide debris, Qls(?), Questionable landslide debris, parentheses where present denote predominate geologic unit composing debris
		Qoal	Older alluvium
		Ql	Lake or pond deposits
		Qps, Qpse	Perched soil or colluvium, Qpse, where noted to be expansive
		Qt	Terrace deposits, undifferentiated
	Pleistocene	Qtr4, Qtr3, Qtr2, Qtr1	River terrace deposits; subscripts denote order of deposition
		Qs	Nonmarine sand of undetermined origin
TERTIARY	Pliocene	Tc	Capistrano Formation
	Miocene	Tm	Monterey Formation
		Tt, Ttso, Tts	Topanga Formation, Ttso, San Onofre Breccia, Tts, siltstone
		Ts	Sespe Formation
	Eocene	Tsau, Tsal	Tsau, upper beds; Tsal, lower beds } Santiago Formation
	Paleocene	Tsi	Silverado Formation
UPPER CRETACEOUS		Kwp	Pleasants Sandstone Member } Williams Formation
		Kwsu, Kws2, Kwsl	Schulz Ranch Member, Kwsu, upper beds, Kwsl, lower beds, Kws2, conglomerate-fanglomerate facies } Williams Formation
		Kl, Klh, Klb, Klbc	Ladd Formation, undifferentiated, Klh, Holz Shale Member, Klb, Baker Canyon Member, Klbc, conglomerate
		Kt	Trabuco Formation
UPPER JURASSIC		Jsp	Santiago Peak Volcanics

SYMBOLS

— — · · ?· —	Contacts, dotted where concealed or altered by development, dashed where approximated, queried where inferred, solid where located with certainty
— c — c —	Denotes Claymont Clay Bed in the Silverado Formation
· · — — ? — ? — 70 U D	Fault, dashed where approximately located, dotted where concealed, queried where conjectural, U-upthrown side, D-downthrown side, arrow indicates attitude. Double line indicates width of zone
〰	Shears
(Tsol)	Landslides. See also Qls under descriptions of units. Queried where questionable
	Landslide scarp or pull away
	Surficial slide or mudflow
〰	Creep
15	Attitude of beds, regional
73	Attitude of beds, local
10	Attitude of joints or minor shears
	Vertical joint or shear
⊕	Horizontal beds
15	Approximate attitude of beds
	Invertebrate fossil locality
	Fossil plant locality
	Prospect oil, boundary
⚒	Mineral prospect
○	Spring or seep
	Anticline
	Syncline
Qsw / Qs	Indicates upper unit thinly overlying lower unit
Res	Reservoir
○	Exploratory drill hole for petroleum
	Exploratory drill hole for petroleum converted to water well

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